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(54) Title of Invention: FILTERING METHOD

(57) Claim

**Claim 1** A filtering method in which the method of filtering a liquid uses planar hollow fiber membrane modules comprising multiple hollow fiber membranes arrayed approximately in parallel and installed in the form of sheets which are disposed so

that their surfaces are horizontal], wherein air supplied from below the planar hollow fiber modules is used to scrub the planar hollow fiber modules either continuously or intermittently, and in which the module hollow fiber membranes are placed under tension, and in which the relaxation ratio is 0-3%.

### Detailed Description of the Invention

0001

#### Industrial Field of Use

This invention relates to filtering methods using hollow fiber membrane modules, and especially pertains to filtering methods that use hollow fiber membrane modules to filter particularly polluted liquids.

0002

#### Prior Art

Typically, hollow fiber membrane modules are used in a wide variety of precision filtering fields such as the production of sterilized water, drinking water, and highly pure water, as well as in air purification. However, in recent years these filters have been considered for use in the treatment of highly polluted water in secondary and tertiary treatment in waste water processing plants and in cleaning tanks for the separation of solids and liquids.

Since the hollow fiber membrane modules used for these applications are subject to a significant amount of clogging during filter processing, they are cleaned by blowing air onto and vibrating the hollow fiber membrane to clean the membrane surface, or the membrane surface is cleaned by repeatedly passing process water in the reverse direction from filter processing.

0004

However, the hollow fiber membrane modules used in these applications are mainly of the tubular-type consisting of bundled tubular or concentric hollow fiber membranes that have typically found uses in precision filtering applications. Furthermore, even if these types were to be improved, typically only the filling ratio or filling shape of the hollow fiber membrane is changed.

0005

### Problems Which the Invention is Intended to Resolve

When these types of prior art hollow fiber membrane modules are used to filter process highly polluted water (for example SS  $\geq$  50 ppm, TOC  $\geq$  100 ppm), sediments consisting of organic and other materials adhering during use to the surfaces of the hollow fiber membranes build up (adhere) between the hollow fiber membranes so that they functionally become one piece, thereby reducing the effective membrane surface area of the hollow fiber membranes, resulting in a dramatic decrease in filter flow volume.

0006

Moreover, even when membrane surfaces of the hollow fiber membrane modules that have adhered together and become functionally one piece in this way are periodically cleaned or backwashed, it is not an easy matter for modules that have adhered together to recover their function, and their cleaning efficiency thus declines.

0007

One proposed way of solving this problem is to use hollow fiber membrane sheets in place of bundled hollow fiber membrane modules, with one end or both ends of the hollow fiber membranes maintained in an open condition by one or two different fixation parts within the housing that install the hollow fiber membrane so that the hollow fiber membrane fixation parts are perpendicular in cross section, and are in any case elongated and approximately rectangular in shape.

0008

This is a module that is well-suited to the filtration of highly polluted water since it is possible with this sort of planar sheet hollow fiber membrane module to dispose the hollow fiber membranes so as to create spaces between the layers and to make the

inner and outer layers uniform, making it possible to control the kind of decrease in filter efficiency that has been seen up until now when washing the membrane surfaces since it is extremely easy to wash the hollow fiber membrane surfaces evenly.

0009

Nevertheless, by installing the planar sheet surface of the hollow fiber membrane module horizontally, relaxing and fixing the hollow fiber membrane, and by using air blown from below to scrub the membrane surface, air bubbles passing through the hollow fiber membrane sheet can cause bunching of the hollow fiber membrane and can to some extent cause clumping of the hollow fiber membrane, forming channels. Air bubbles can pass through these areas in a concentrated fashion and can make it impossible to perform efficient membrane surface cleaning of the entire module.

0010

Moreover, by sufficiently relaxing in the hollow fiber membrane (for example, a relaxation ratio of 5%), the hollow fiber membrane becomes buoyant and arches in water when the planar hollow fiber membrane module is installed. Furthermore, the width of vibration of the hollow fiber membrane as a result of air scrubbing becomes larger.

0011

Therefore, among other problems that can occur, a substantial amount of stress buckling occurs in the area between the hardened potting resin area that fixes the hollow fiber membrane gathered area and the base areas of the individual hollow fiber membranes as a result of the substantial vibration applied to the hollow fiber membrane. As a result of a deterioration in the strength of the interface parts, cracks and breaks occur in the hollow fiber membrane in between the hardened resin area and the hollow fiber membrane, which tend to destroy the

module functionality over short periods of use.

0012

The purpose of this invention is to provide a filtering method using the sheet-type planar hollow fiber membrane module of this invention, solving these problems associated with sheet-type planar hollow fiber membrane modules used to filter liquids, particularly highly polluted water, and to permit efficient washing of the entire module that can be done in the context of a filtering method that uses a sheet-type planar hollow fiber membrane module, and in which damage to the hollow fiber membrane does not occur in the vicinity of the interface between the hardened potting resin area and the hollow fiber membrane.

0013

#### Means of Solving the Problems

The present invention is principally a filtering method in which planar hollow fiber membrane modules comprising multiple hollow fiber membranes arrayed approximately in parallel and installed in the form of sheets which are disposed so that their surfaces are horizontal, wherein air supplied from below the planar hollow fiber modules is used to scrub the planar hollow fiber modules either continuously or intermittently, and in which the module hollow fiber membranes are placed under tension, and in which the relaxation ratio is 0-3%.

0014

The following detailed description of the invention is made with reference to the drawings. Fig. 1 is a perspective drawing of an example of a hollow fiber membrane supporting method for the filtering method of the present invention using a sheet-type planar hollow fiber membrane in which the sheet surface is horizontal in a tank or can, the modules are installed without applying tension to the hollow fibers, and three modules are layered from top to bot-

tom.

0015

Fig. 2 is a perspective drawing of an example using the support method shown in Fig. 1. Here, the three modules are installed and layered one above the other, and the lengthwise direction of the hollow-fibers of the central module runs perpendicular to the lengthwise hollow fibers of the adjoining modules. In the drawing, 1 is a water collection pipe, 2 is a hollow fiber membrane, 3 is a hollow fiber membrane binder edge part, 4 is an air diffuser plate.

0016

The planar hollow fiber modules used in this invention are hollow fiber membranes arrayed approximately in parallel in the form of sheets which are hollow fiber membranes 2 that are installed and maintained at one end or both ends in an open condition by means of potting resin, and the hollow fiber membrane 2 openings pass through the collector pipe.

0017

The hollow fiber membrane 2 need not be limited to being connected in an opened state on one side to the collector pipe 1, and may just as well be connected and maintained on both sides in an opened state with water collection pipes on both ends. Thus, it does not matter if the hollow fiber membrane binder part 3 is a water collection pipe in both drawings.

0018

The hollow fiber membranes 2 should be tensioned as much as possible when the modules are installed, and the relaxation ratio of the hollow fibers must be 0-3%, and preferably between 0-1%. Since the hollow fibers are not all of uniform length, it would be difficult in practice to hold the hollow fibers fixedly in a completely tensioned state. However, there is no impediment to obtaining the

effect if the relaxation ratio of the hollow fibers is under 3%, and preferably under 1% in the installed state.

0019

A variety of methods may be used to install the modules in tanks and cans, including stands, clamps, and dedicated fixtures used to fix the modules, but any installation method may be used as long as the modules do not move when performing air scrubbing or other operations.

0020

The air diffuser plate 4 is used for air scrubbing, but any type may be used as long as the air bubbles reach every part of the modules. Therefore, although the drawing shows an air diffuser plate, it is equally acceptable to use air diffusers consisting of perforated pipe or of porous material.

0021

The air diffuser plate or air diffuser pipe is connected to a blower and membrane surface cleaning is effected by continuously or intermittently running the blower during filtering.

0022

When building up a plurality of modules in layers from top to bottom, such methods as shown in Fig. 1, wherein the hollow fiber membranes are oriented parallel to each other, or as in Fig. 2, wherein the hollow fiber membranes are layered so that in their lengthwise directions they intersect one another perpendicularly, etc. Moreover, although it is desirable to make the can or processing tank as compact as possible by reducing the spacing in between the adjoining modules, module spacing can be determined on the basis of the number of modules, air scrubbing conditions, and other parameters.

0023

Such materials as cellulose fiber, polyolefin fiber, polyvinyl alcohol fiber, PMMA fiber, polysul-

fone fiber may be used for the hollow fiber membrane 2, but such materials as polypropylene, with its high elasticity, are particularly desirable.

0024

Although there are no limitations on the filtering membrane, as long as the membrane can be used, in terms of hole size, porosity, membrane, thickness, outer diameter, etc., if one considers the material(s) to be removed, ensuring membrane surface area to volume, and the strength of the hollow fiber membrane, among others, ranges for hole diameters of 0.01-1  $\mu\text{m}$ , porosity of 20-90%, membrane thicknesses of 5-300  $\mu\text{m}$ , and outer diameter of 20-2000  $\mu\text{m}$  can be suggested.

0025

Moreover, it is necessary for the hole diameters to be less than 2  $\mu\text{m}$  if the goal is to remove bacteria, and if the goal is to remove organic materials and viruses there may be times when ultrafiltration of from several tens of thousands molecular weight to several hundreds of thousands molecular weight fractioning is used.

0026

In terms of the surface characteristics of the hollow fiber membrane, it is preferable that the surface of the hollow fiber membrane hold polymers such as saponified ethylene vinyl acetate copolymers so that the surface of the hollow fiber membrane has hydrophilic properties, and is a so-called permanent hydrophilic membrane. If the hollow fiber membrane is hydrophobic, a hydrophobic effect takes place between the organic materials in the process water and the surface of the hollow fiber membrane, organic materials adhere to the membrane surface, resulting in blockage of the membrane surface and reduced filter service life.

0027

It is usually difficult to recover filtering per-

formance by washing a membrane surface that has become clogged by adhesions. By using a permanent hydrophilic membrane, it is possible to reduce the hydrophobic effect between organic compounds and the hollow fiber membrane surface, thereby controlling the amount adhesion of organic materials.

0028

#### Operation of the Invention

When filtering is performed with the sheet surface of the module put in a horizontal position and the module fixed in place, the hollow fiber membrane is placed in a tensioned condition without being relaxed. It becomes hard for the membranes to converge with one another or for clumps of adhesions to form, and it also makes unlikely the formation of channels during air scrubbing from below. Therefore, air bubbles are apt to make contact evenly over the entire hollow fiber membrane within the module, and cleaning of the membrane surface throughout the entire module can be performed efficiently.

0029

Since the hollow fiber membranes are tensioned, the amount of buckling due to stress of the hardened potting resin areas that fix the hollow fiber membrane binder edge part or of the individual base parts of the hollow fiber membranes can be reduced since the width of vibration of the hollow fiber membranes remains controlled and the hollow fiber membranes do not become arc-shaped even if the hollow fiber membranes pick up buoyancy.

0030

When the sheet surfaces are placed horizontally with the hollow fiber membranes placed under tension and the modules installed, and a plurality of modules are disposed in layers in a can or tank, by layering and affixing the modules so that in their lengthwise directions the adjacent modules intersect

one another perpendicularly, the channels formed by air bubbles to a certain extent can be eliminated by the module directly underneath, thereby making it easier for the air bubbles to make contact with the various modules uniformly.

0031

#### Embodiments

A specific explanation of this invention will made with reference to the following embodiment.

**Embodiment 1. Comparative Example 1**

A comparison of differential pressure rise during filtering operations due to differences in the relaxation ratio at time of module installation was performed using a planar hollow fiber membrane module having a membrane surface area of 2 m<sup>2</sup> comprised of poly(ethylene) hollow fiber membrane holding on its surface saponified ethylene vinyl acetate copolymers. The module was installed so that the sheet surface was horizontal within the tank and was supported. The tank was filled with water in which 200 ppm of yeast was placed in suspension, and this water was used as the raw water upon which to perform filtration. For the filtration method, the module was completely immersed in the raw water. The inlet of a pump was attached to the water collection pipe, and filtration was performed using the pump's suction.

0032

The pump's flow rate was set at a fixed 330 ml/min (LV = 0.0099 m<sup>3</sup>/h), and a single cycle consisted of filtering for 5 minutes, then 5 minutes off (stopping the pump). Air bubble cleaning was performed with a continuous stream of air at 35 Nl/min from below the sheet surface during operation(both during filtration and when filtration was stopped). Filtering was performed both with a module having a relaxation ratio of 0.5% when supported and with a comparative example having a relaxation ratio of 4%.

0033

Fig. 3 graphically shows the differential pressure (suction pressure) behavior of modules supported in a tank with these different relaxation ratios when operated under the conditions outlined above. It is clear that the rise in differential pressure was controlled more with a relaxation ratio of 0.5% rather than one with a relaxation ratio of 4%, thereby making it possible to maintain stable filtering.

0034

#### Effect of the Invention

When air scrubbing is performed continuously or intermittently during filtering operations in filtering methods using planar hollow fiber membrane modules of this invention, the air reaches the entire hollow fiber membrane of the module, and cleaning efficiency is increased.

0035

Cleaning efficiency is increased and it is possible to maintain a high level of filtering flow volume over long periods of time particularly in the case of highly polluted water. Moreover, the amount of stress concentrated on the interface between the hardened potting resin area and the hollow fiber membrane can be reduced and damage to the hollow fiber membrane controlled.

#### Brief Description of the Drawings

Fig. 1 Perspective drawing showing an example of a method of supporting hollow fiber membrane modules in the context of the filtering method using the sheet-type planar hollow fiber membrane module of this invention

Fig. 2 Perspective drawing showing an example of a method of supporting hollow fiber membrane modules in the context of the filtering method using the

sheet-type planar hollow fiber membrane module of this invention

Fig. 3 Graph showing the differential pressure behavior of hollow fiber membrane modules having 0.5% and 4% relaxation ratios under conditions of continuous filtering operation

**Description of Symbols**

- 1 Water collection pipe
- 2 Hollow fiber membrane
- 3 Hollow fiber membrane binder edge part
- 4 Air diffuser plate.

Figs. 1 and 2: [caption] Air from blower

Fig. 3 [x-axis] Days of operation (days)

[captions in graph:] Relaxation rate 4%

Relaxation rate 0.5%

Front page, continued

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## Certification

I, Alex Kent, a professional translator, hereby certify that the attached English document, Patent Publication No. 2946072, is a true and faithful translation from the Japanese language.

By

Alex Kent Sept. 1, 2004